Testing cosmic ray composition models with very large volume neutrino telescopes

Luigi Antonio Fusco[1+], Federico Versari[2]

[1] CPPM, Marseille [2] INFN, Bologna
[+] fusco@cppm.in2p3.fr

Atmospheric neutrino fluxes are influenced by the composition of the Cosmic Ray (CR) primary flux, at energies above a few TeV and up to the highest energies. These differences can be zenith dependent given the different interaction lengths of nuclei in the atmosphere **[fig.1]**.

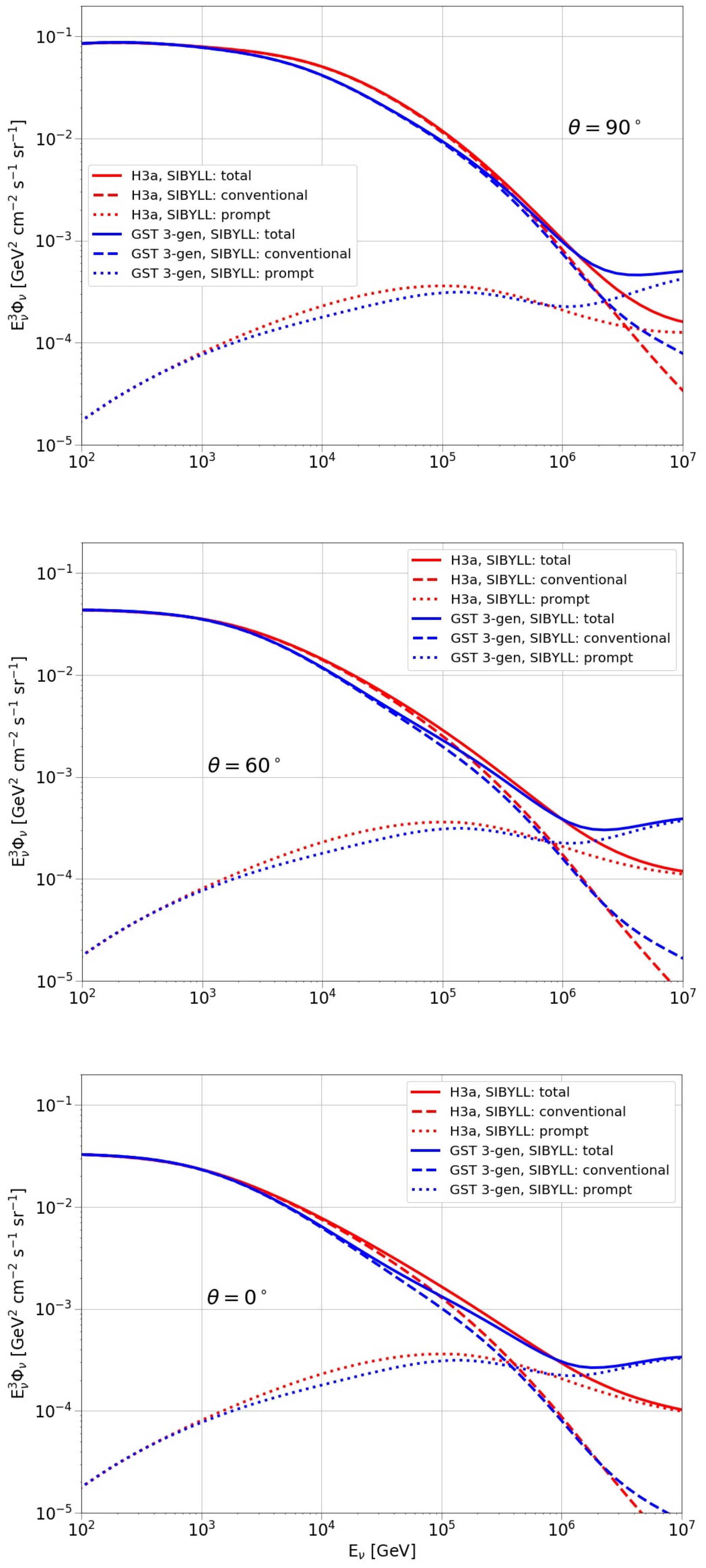

Figure 1. *Muon neutrino fluxes for three different zenith angles according to the same SYBYLL 2.3c hadronic interaction model, changing the CR composition fit* ***[ref. 2]***.

MCEq [ref. 1] allows to quickly produce differential lepton fluxes according to different models.

The atmospheric neutrino flux also is influenced by how the **hadronic interactions** can be modeled **[fig.2]**, especially at the first interactions as particles showers down the atmosphere. Other secondary effects, such as the atmospheric temperature and density profile, can also be affecting the measurements **[ref. 3]**.

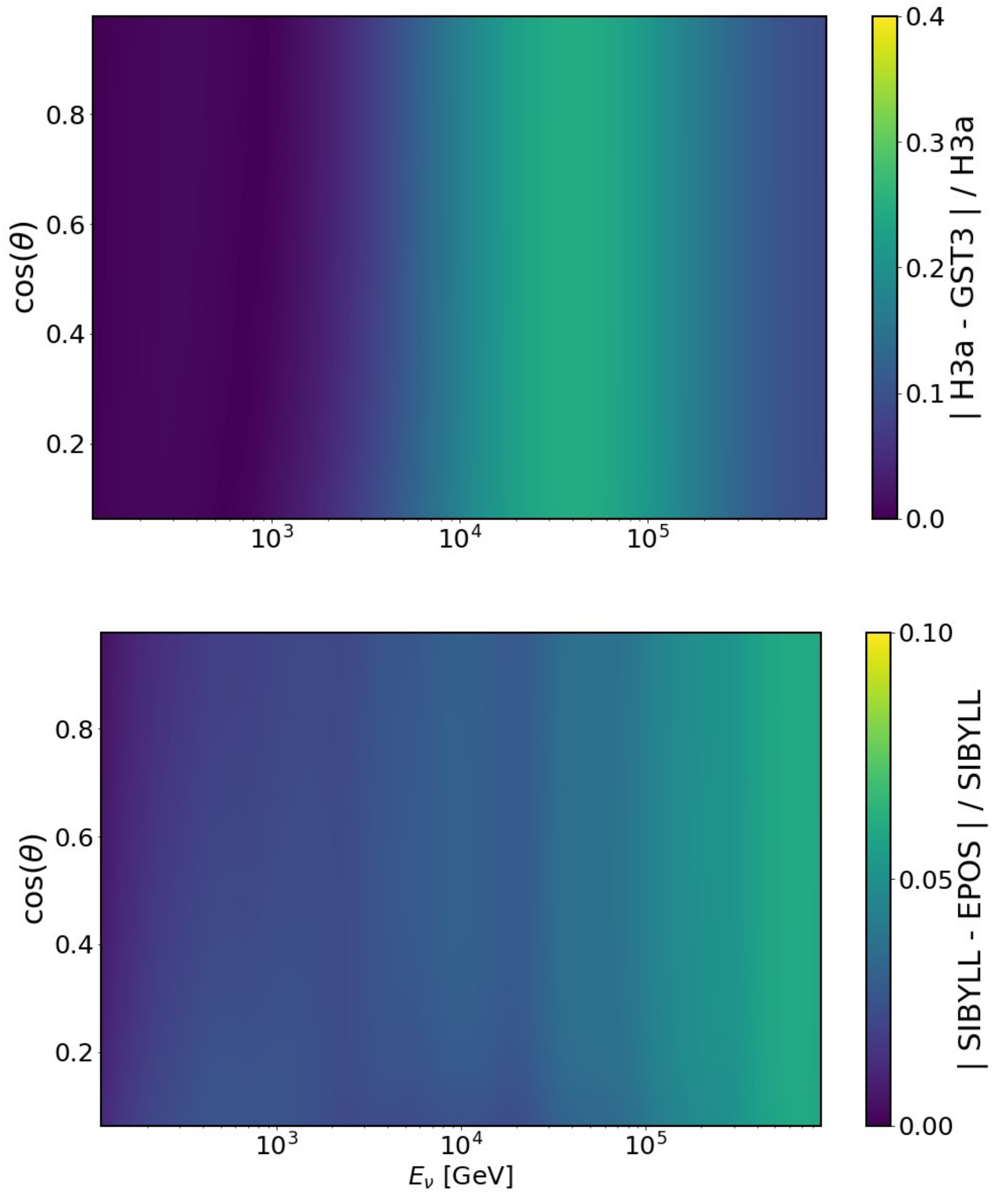

Figure 2. *Muon neutrino flux ratios as a function of zenith and energy for different CR composition models (top) and hadronic interaction models (bottom)* ***[ref.4 and 5]***

Large volume neutrino telescopes allow to collect a large statistics of neutrino events thanks to their large effective areas **[fig. 3]**. The detector response in energy can be modeled according to the expected energy resolution – here assumed to be Gaussian with a possible systematic shift. The neutrino flux, convoluted with the effective area and the energy response, produces the expected event rates at the detector.

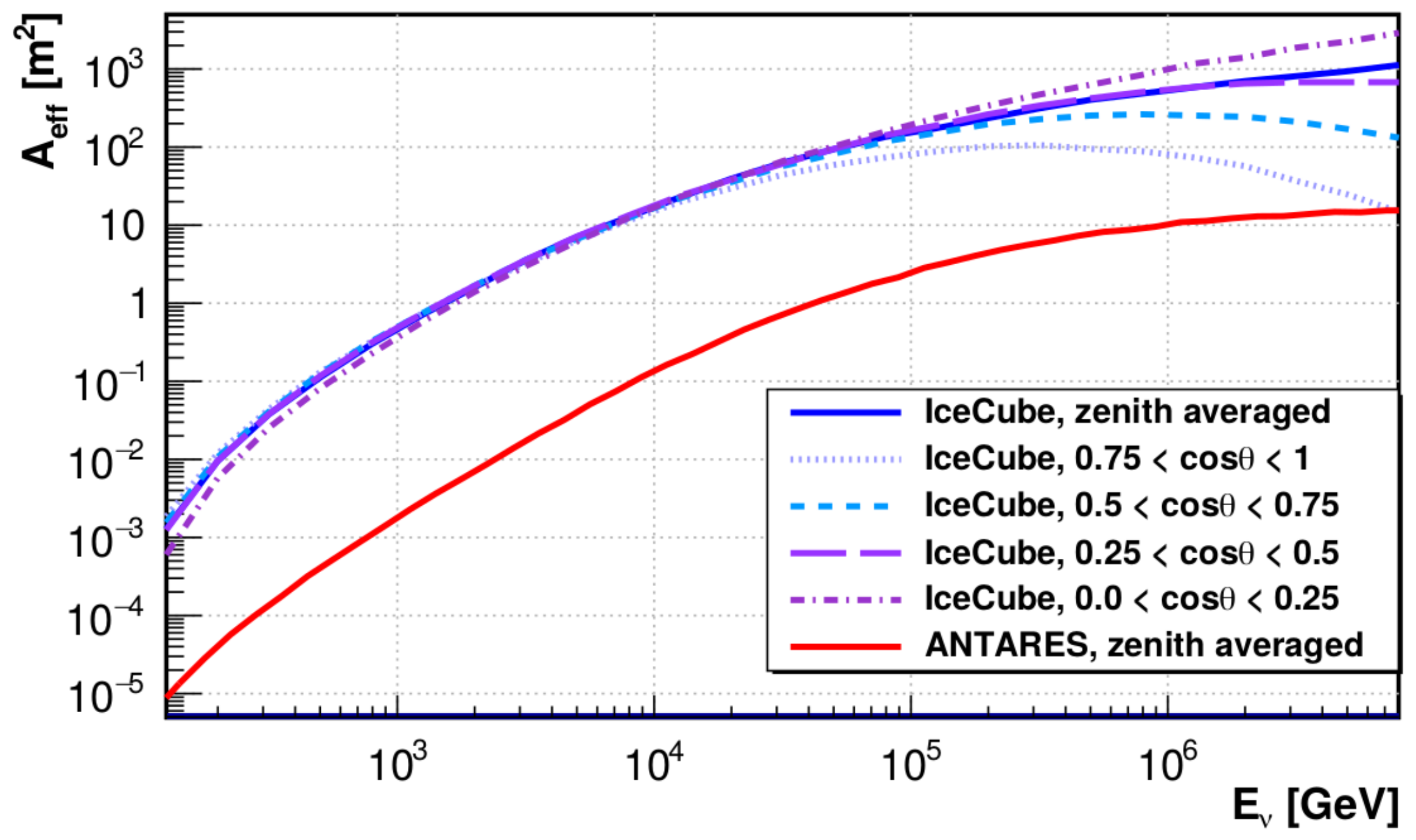

Figure 3. *Muon neutrino effective area for the IceCube* ***[ref.6]*** *and ANTARES detectors* ***[ref. 7]***

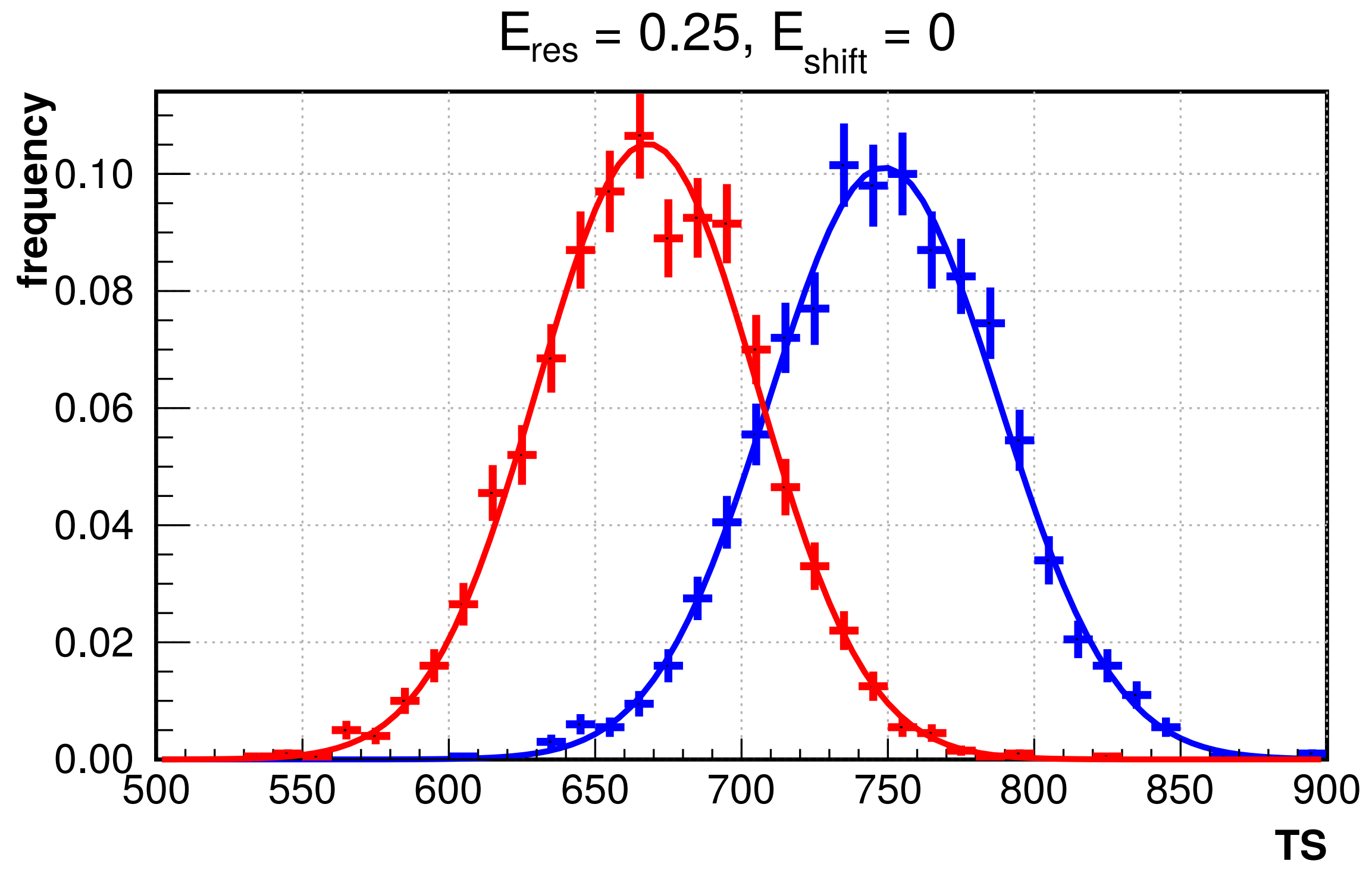

Figure 4. *Log-Likelihood ratios for the two CR composition assumptions assuming 10yr of IceCube-equivalent data-taking with energy resolution equal to 0.25 in logE and no systematic shift.*

A binned **Maximum Likelihood test [fig. 4]** has be applied on simulated pseudo-data sets equivalent to 10 years IceCube **[fig. 5]**. We find that a **~2σ** separation between CR composition models can be achieved, and further improvements can be obtained boosting the energy reconstruction performance, as expected in the next generation neutrino telescopes.

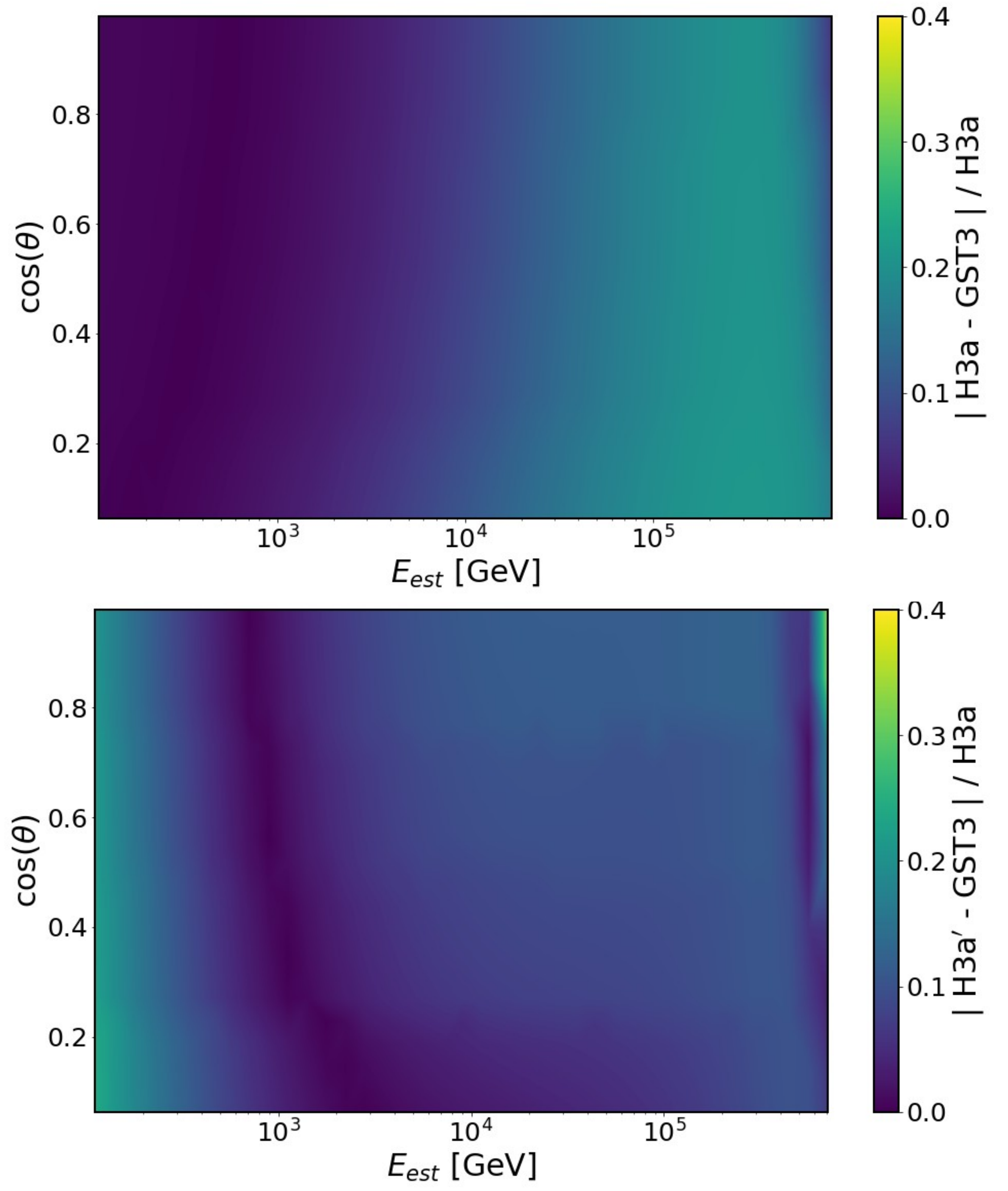

Figure 5. *Muon neutrino smeared event rates ratios for different CR composition models assuming a 0.5 logE resolution and no systematic shift (top) or 0.1 logE systematic shift (bottom).*

References

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